The Impact of Shift, Circadian Typology, and Bright Light Exposure on Sleepiness, Vigilance, and Driving Performance in Hong Kong Taxi Drivers

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ABSTRACT

Sleepiness has been consistently found to be a common problem in drivers, and its detrimental effects on vigilance and driving performance are well documented. However, naturalistic studies are limited, and this important health problem has not been studied in Hong Kong. In the present naturalistic study, a group of professional drivers, specifically taxi drivers, served as the participants because local statistics revealed their higher vulnerability to traffic accidents. The purposes of the present study were to (1) examine how sleepiness as well as vigilance and driving performance of taxi drivers varied within one shift and whether these changes differed between daytime and nighttime drivers, (2) investigate whether matching drivers' shift with their circadian typology was beneficial to drivers' sleep, (3) examine the mediating role of sleepiness in the relationship between disturbed sleep and vigilance and driving performance, and (4) determine whether exposure to bright light facilitated work adaptation of nighttime drivers. Thirty-two urban taxi drivers (16 daytime and 16 nighttime) were recruited after initial screening for their circadian type. Results showed that (1) both daytime and nighttime drivers showed deterioration in their subjective alertness, but improvement in vigilance and driving performance throughout a shift; (2) for daytime taxi drivers, the more morning-typed they were, the higher their sleep quality was, and for nighttime taxi drivers, a similar trend between high eveningness and high sleep quality was observed; (3) sleepiness did not mediate the impact of disturbed sleep on vigilance and driving performance; and (4) bright light exposure impaired drivers' vigilance and simulated driving performance, and it failed to help drivers maintain their alertness throughout a shift. The present study has both theoretical and practical significance: job performance should not be

incorporated into the theoretical model about shift work adaptation proposed by Barton and her colleagues (1995); it is possible that matching shift and circadian type is associated with improved shift workers' sleep; and very brief bright light exposure impairs job performance of permanent night shift workers who are used to working in a dark environment.

摘要

疲倦是司機經常遇到的問題，其對警覺性及駕駛表現的害處亦記載於不少文獻·可是，過往的研究較少在工作環境中進行，加上在香港，從來沒有研究探討過這個健康問題·是次研究是在工作環境中進行，並且採用一群職業司機（的士司機）爲受試者，因爲本港的研究數字指出職業司機，特別是的士司機，較容易遇到交通意外·是次研究的目的包括：（一）探討司機的疲倦、警覺性及駕駛表現於一更內的轉變，及研究日更的士司機和夜更的士司機的轉變會否不同；（二）研究配合日／夜更及的士司機的日／夜間活動型性格會否有助睡眠；（三）探討睡眠、疲倦、警覺性及駕駛表現的關係；以及（四）研究強光治療能否幫助夜更的士司機適應其夜更工作·經過初部甄選後，三十二位的士司機（十六位日更及十六位夜更）成爲是次研究的受試者·研究結果顯示（一）由開始到結束工作，日更及夜更的士司機都會感覺越來越疲倦，而其警覺性及駕駛表現則會越來越好；（二）日更的士司機越接近日間活動型性格，睡眠質素越好，而夜更的士司機則有越接近夜間活動型性格，睡眠質素越好的傾向；（三）疲倦不是睡眠和警覺性及駕駛表現的關係的中介者；以及（四）強光治療損害夜更的士司機的警覺性及駕駛表現·是次研究於理論層面和實際層面上都有重大的貢獻：Barton 及其同僚(1995)建議有關輪班工作的理論模型不應包括工作表現；配合日／夜更及日／夜間活動型性格可能有助睡眠；以及過短的強光治療有損已習慣在漆黑環境工作的長期夜更工作者的工作表現·

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CHAPTER 1

Introduction

Driver sleepiness is a health problem that has attracted the attention of researchers because of its high prevalence (Benbadis, Perry, Sundstad, & Wolgamuth, 1999; Connor et al., 2001; Corfitsen, 1993; Dalziel & Job, 1997; Häkkänen & Summala, 2000; McCartt, Ribner, Pack, & Hammer, 1996; McCartt, Rohrbaugh, Hammer, & Fuller, 2000; Oron-Gilad & Shinar, 2000; Ozturk, Tufan, & Guler, 2002), and its close association with traffic accidents (Corfitsen, 1993; Flatley, Reyner, & Horne, 1998; Häkkänen & Summala, 2000; Horne & Reyner, 1995a; Liu et al., 2003; Maycock, 1997; McCartt, Ribner, Pack, & Hammer, 1996; Ozturk et al., 2002; Pack et al., 1995; Sagberg, 1999). Although numerous studies about sleepiness in professional drivers have been conducted in western countries, only three have investigated this problem in taxi drivers. This is clearly a fertile area for research because in Hong Kong taxi drivers were involved in the largest proportion of traffic accidents involving professional drivers from 1998 to 2003 (Transport Department, 2004a), yet no study about driver sleepiness had ever been conducted. Also, previous studies were mainly laboratory studies, so in the present study, participants were tested in a naturalistic enviroment. The present study aimed at (1) determining the changes in Hong Kong taxi drivers' sleepiness as well as vigilance and driving performance within one shift and comparing the size of these changes between daytime and nighttime drivers, (2) examining whether a match between drivers' shift and their circadian typology improved their sleep quality and quantity, (3) determining the mediating role of sleepiness in the relationship between disturbed sleep and performance, and (4) investigating whether bright light exposure helped nighttime drivers adjust better to their shift.

Why is empirical research on driver sleepiness important?

Driver sleepiness is a hot health issue in western countries because its prevalence rate is high across countries, and it is closely linked with traffic accidents.

Prevalence of driver sleepiness

Driver sleepiness is a worldwide health problem. As listed in Table 1, the prevalence rates have been found to vary from 4.8% to 54.6% (Benbadis et al., 1999; Connor et al., 2001; Corfitsen, 1993; Dalziel & Job, 1997; Häkkänen & Summala, 2000; McCartt et al., 1996; McCartt et al., 2000; Oron-Gilad & Shinar, 2000; Ozturk et al., 2002). The differences among countries may be attributed to the use of different criteria and the inclusion of different driving populations.

The severity of sleepiness in drivers was measured by either subjective evaluation of sleepiness (Benbadis et al., 1999; Connor et al., 2001; Corfitsen, 1993; Ozturk et al., 2002), or reporting past incidences of falling asleep at wheel / driving while drowsy. For the latter, drivers were asked to report the incidence in the previous three months (Häkkänen & Summala, 2000), in the previous year (McCartt et al., 1996; McCartt et al., 2000; Oron-Gilad & Shinar, 2000), in the previous two years (Dalziel & Job, 1997), or during their lifetime (McCartt et al., 2000). However, no consistent pattern in the relationship between prevalence rate and criteria (subjective evaluation vs. recall, or long vs. short time period) can be observed.

Another possible explanation for the variations is that different types of drivers were involved in past studies. Generally, the prevalence is higher in professional drivers, e.g. truck drivers (Häkkänen & Summala, 2000; McCartt et al., 2000; Oron-Gilad & Shinar, 2000), taxi drivers (Corfitsen, 1993; Dalziel & Job, 1997; Ozturk et al., 2002) and bus drivers (Ozturk et al., 2002), than randomly selected licensed drivers (McCartt et al., 1996) and drivers recruited in a government transport department (Benbadis et al., 1999) or at roadside (Connor et al., 2001). In fact, this argument has been validated in a past study which stated that sleep debt was more common in professional drivers than the general population (Carter, Ulfberg, Nystroem, & Edling, 2003). This may be related to the larger number of continuous hours spent by professional drivers on the road and their relatively limited rest during work. The longer the shift professional drivers work, the more they earn. Because of the higher prevalence of sleepiness in professional drivers, a professional driving population, taxi drivers, was examined in the present study.

Driver sleepiness as a risk factor for traffic accidents

Both acute and chronic sleepiness are risk factors for traffic accidents. Connor and her colleagues (2002) included two kinds of drivers (case and control) in a study that aimed at determining the role of sleepiness in traffic accidents (Connor et al., 2002). Case drivers were individuals who were involved in a traffic accident in which at least one person was admitted to hospital or killed, and they were interviewed in hospital or by telephone at home. Control drivers were recruited while driving on public roads, and telephone interviews were conducted later. The authors found an 8-fold increase in the risk of experiencing an injury in a traffic accident in drivers who were more sleepy at the time of the accident (score of Stanford Sleepiness Scale from 4 to 7) than less sleepy drivers (score 1-3) after the effects of age, sex, socioeconomic status, ethnicity, and alcohol were controlled. When compared with the most alert drivers (score 1), an 11-fold increase in risk was found. A smaller role of chronic sleepiness was demonstrated in a recent study that used a similar methodology and was conducted in Shenyang, a Chinese city (Liu et al., 2003). More chronically sleepy drivers (score of Epworth Sleepiness Scale from 10 to 24) had twice the risk of traffic accidents than less chronically sleepy drivers (score 0-9). The smaller effect may be due to the exclusion of accidents that occurred from midnight to 05:00 – the period of time in a day when accidents related to driver sleepiness are most likely to happen (Folkard, 1997; Hamelin, 1987; Horne & Reyner, 1995a; Horne & Reyner, 1995b; Langlois, Smolensky, Hsi, & Weir, 1985). In fact, when accidents round the clock were studied, severe chronic sleepiness (score 16-24) increased the risk of sleep-related accidents by 18-fold as compared with mild chronic sleepiness (score 0-4) (Stutts, Wilkins, Osberg, & Vaughn, 2003).

Sleep-related traffic accidents are common worldwide as illustrated by both police statistics and drivers' self-report. Based on information obtained from the police, 16% of the traffic accidents in England (Horne & Reyner, 1995a) were related to driver sleepiness. In a large-scale self-report study conducted by Sagberg (1999) in Norway, all 29,600 drivers who were involved in traffic accidents in the first few months of 1998 were sent a questionnaire, and 9,200 responded. It was found that 3.9% of the accidents were due to sleep or drowsiness. In another large-scale study of 4,621 male drivers in the UK, 7% of the respondents attributed their accidents to tiredness (Maycock, 1997). In a telephone survey with 1,000 licensed drivers in the USA, 2.8% reported the experience of falling asleep at wheel and having an accident, and 1.9% said that they were drowsy when driving and crashed their cars (McCartt et al., 1996). The figure in professional drivers is higher. Eleven percent of the commercial truck drivers in Finland had a traffic accident at work at least once as a result of falling asleep when driving (Häkkänen & Summala, 2000), and 17% of the taxi drivers and bus drivers in Turkey also had the same experience (Ozturk et al., 2002).

The cost of sleep-related traffic accidents is immense. Although recent reports are lacking, Leger (1994) estimated that in the USA a total cost of $29.2-37.8 billion was involved in 1988. The true amount may be higher since only those accidents that happened when sleepiness was most likely and that occurred at night were included in the estimate.

Although the prevalence of sleep-related traffic accidents has been found to be quite high in foreign countries, in Hong Kong, only 87-93 traffic accidents were attributed to drivers who were asleep or drowsy annually from 2000-2003, and this constituted about 0.56-0.61% of the total number of accidents (Transport Department, 2004a). Among these sleep-related accidents, every year, 2-4 (2.2%-4.5%) were fatal, while 22-34 (25.3%-38.6%) and 50-63 (56.8%-72.4%) involved serious and slight injury, respectively. These figures seem small as compared to other causes of traffic accidents, e.g. driving too close to vehicle in front (9.5%-13.7% of annual total accidents), but it is possible that some of these accidents were actually due to driver sleepiness. For instance, not every driver whose car is close to other vehicles has an accident, but if the drivers are falling asleep at the wheel, their reaction may not be fast enough to respond when the car in front suddenly comes to a stop. Indeed, a previous study showed that some of the sleep-related traffic accidents in the UK were mistakenly attributed to driver error and tyre deflation (Flatley et al., 1998). It should also be noted that the accidents included in the Transport Department statistics included only those personal injury accidents reported to the police and did not take damage-only accidents into account. This may further explain why the number of sleep-related accidents seems small as compared to other countries.

Underestimation of the prevalence of both driver sleepiness and sleep-related accidents may be due to several reasons. As suggested by Hulbert (1972), only drivers who fell asleep and were not lucky had accidents, but the number of drivers who were sleepy but fortunate enough to avoid crashing their cars could not be accurately estimated. In addition, it is possible that sleepy drivers do not admit their physical condition at the time of accidents because of the subsequent legal responsibility, thus contributing to the underestimation in police statistics. In order to minimize such inaccuracy and bias in the present study, the participants were guaranteed anonymity, and the independence of this study from the police department was emphasized.

One important point that should be highlighted is that sleep deprivation, which is closely linked with sleepiness, has the same effect as alcohol on driving performance (Powell et al., 2001). This is also indirectly reflected in the similar annual numbers of accidents attributed to driver sleepiness and consumption of alcohol in Hong Kong (Transport Department, 2004a). As mentioned previously, about 90 accidents involved a sleepy driver every year, while the number of accidents caused by intoxicated driving varied from 60 to 106 from 2000 to 2003 with an average of about 80 for each year. Except for 2003, alcohol-related accidents were less prevalent than sleep-related ones. Nevertheless, in Hong Kong, much effort has been devoted to campaigns that aim at educating people not to drive after drinking alcohol and laws are frequently enforced by the police, while very limited public education about preventing driving when sleepy has been promoted, and this kind of dangerous driving has not been rendered illegal. This further strengthens the need for empirical research on driver sleepiness and its impact in Hong Kong.

Why should taxi driver sleepiness be studied?

Researchers should investigate taxi driver sleepiness because of three reasons: taxi drivers are highly vulnerable to road traffic accidents as well as sleepiness while driving, their sleepiness problem has not been thoroughly studied, and they play a significant role in public road transport in Hong Kong.

Consistent with foreign findings (Carter et al., 2003), professional drivers as a group contributed to a larger percentage of traffic accidents in Hong Kong when compared with private car drivers (Transport Department, 2004a). This pattern has persisted for the past ten years. From 1994 to 1997, light goods vehicles contributed to the largest proportion of accidents among all kinds of professional drivers (public light bus, light goods vehicle, medium vehicle, heavy goods vehicle, public bus, taxi, tram, and light rail vehicle). However, since 1998, accidents were highest among taxi drivers. The percentage was quite stable from 1998 to 2003 (28.0% - 31.7%), and a total of 18,234 accidents involved taxi drivers. This is equivalent to about 20% of all the traffic accidents (including both professional and other kinds of drivers) every year. The high occurrence of accidents in this driving population is also evident in that in the past ten years, for every 1,000 taxis, 172.0-209.9 were involved in accidents annually. From 2000 to 2003, a total of 76 people were killed in accidents involving taxis, and another 2,353 and 14,412 people were respectively seriously and slightly injured.

However, this driving population has been understudied in both Hong Kong and foreign countries. No study has been performed in Hong Kong, while in foreign countries, only three studies involved solely taxi drivers (Corfitsen, 1993; Dalziel & Job, 1997; Edwards, Hahn, & Fleishman, 1977), but they were conducted for different purposes. One was for evaluating the relationship between performance in a driving simulator and on streets (Edwards et al., 1977). The other two studies were both related to the prevalence of sleepiness in taxi drivers. Dalziel and Job (1997) recruited 42 participants from a taxi network. Only two of them reported in a questionnaire that they had fallen asleep at the wheel while driving a taxi in the past two years, and both of them were not involved in any sleep-related accidents. In Corfitsen's (1993) study, the prevalence of sleepy driving was found to be much higher as a different methodology was used. Among the 120 taxi drivers who were stopped and surveyed on a major highway, one in three reported that they were either very tired or tired, while the rest described themselves as rested. The on-the-road report by drivers may be more accurate as this is not subject to the problem of recall. Consequently, participants' current subjective evaluation of sleepiness, instead of past experience, was used in the present study.

When compared with other professional drivers, particularly truck drivers (e.g. Häkkänen & Summala, 2000; Hamelin, 1987; McCartt et al., 2000; Mitler, Miller, Lipsitz, Walsh, & Wylie, 1997; Oron-Gilad & Shinar, 2000), the effort devoted to the sleepiness problems and the driving performance of taxi drivers has been limited. This may be due to the fact that taxis constitute a smaller proportion of vehicles on the road and trucks are more frequently used in foreign countries than in Hong Kong.

In Hong Kong, taxis form one of the major kinds of public transport. According to the Transport Department (2004b), there were 18,138 taxis in May 2004 in Hong Kong. About 500 million passenger journeys are made by taxis every year, and this is equivalent to about 12-14% of the total number of journeys among all kinds of public transport (Transport Department, 2003).

In conclusion, because of the high involvement of taxis in traffic accidents in Hong Kong, the severity of sleepiness of taxi drivers, as well as the relatively limited knowledge about sleepiness and its consequences in this population, taxi drivers (both daytime and nighttime) were included in the present study.

Variations in sleepiness and vigilance and driving performance within a shift and comparison between daytime and nighttime drivers

Taxi drivers need to work long hours, and a number of studies have revealed that sleepiness increases throughout prolonged driving. For example, in a study in which participants needed to keep a small car on a narrow moving road continuously for four hours, participants' subjective ratings of sleepiness as well as difficulty to keep their eyes open increased significantly over time (Dureman & Boden, 1972). O'Hanlon and Kelley (1977) divided their participants into good and poor drivers in terms of their frequency of lane drifting, and found that both groups showed a decreasing trend of subjective alertness over the course of driving for 4-5 hours. Blink frequency also increased over a 12-hour drive which was divided into four sessions with each separated by a 30-minute break, and this implied that the participants tried harder to remain alert when they were fatigued (Summala, Häkkänen, Mikkola, & Sinkkonen, 1999).

Decrements in vigilance and driving performance in a night drive have been demonstrated. In a previous study (Riemersma, Sanders, Wildervanck, & Gaillard, 1977), participants drove continuously at night for eight hours and were required to report every time their odometer reached a multiple of 20 and press a button whenever a light changed colour. Their performance in these vigilance tasks was poorer in the second half of the study than in the first half. Driving performance was also found to deteriorate over time in that increasing trends (though not significant) in the standard deviation of lane position and speed were observed.

Sleepiness and driving impairment are more serious at night than during daytime (e.g. Åkerstedt, Torsvall, & Gillberg, 1982). Härmä, Sallinen, Ranta, Mutanen, and Müller, (2002) showed that 49% of the train drivers reported severe sleepiness when working a night shift (22:00-06:00), whereas when working a morning shift (05:30-13:30), 20% of them had this problem. The prevalence was even smaller when working an evening shift (13:30-22:00) or a day shift (09:00-16:00), which was 6% and 4% respectively. With the level of sleepiness during day shift as baseline, train drivers had a 14-fold increase in risk of severe sleepiness when working a night shift, and a two-fold increase in risk was found in a morning shift.

Additional evidence for the higher vulnerability for sleepiness and driving problems in night-shift professional drivers is that working the night shift increased the risk for sleep-related traffic accidents 14-fold as shown by Stutts and her colleagues (Stutts et al., 2003). However, it should be noted that in their study, police data were examined and thus included both professional and private drivers. Nevertheless, night-shift professional drivers spent more time on the road every day than other night-shift workers who only drove at night when returning home after work. Indeed, this study also showed that daily driving time and the percentage of driving time during darkness were both risk factors for sleep-related traffic accidents. Driving for five or more hours increased the risk five-fold as compared to driving less than one hour every day. When driving was conducted in the dark for 75% or more of total driving time, the risk showed a six-fold increase as compared to when the percentage was less than 10%. Furthermore, drivers who drove 25% or more of their time between midnight and 6 a.m. had an eight-fold increase in risk over those who never did so.

In conclusion, previous studies showed that throughout the course of driving, sleepiness level increased and vigilance as well as driving performance deteriorated with these problems being more serious in nighttime drivers. Based on these findings, it was hypothesized that from the beginning to the end of a shift, the sleepiness level of drivers would increase and their vigilance and driving performance would deteriorate (hypothesis 1a), and that the deterioration would be larger in nighttime drivers than in their daytime counterparts (hypothesis 1b). Hence, it was expected that there would be a significant interaction between shift and time on shift.

The impact of circadian typology on sleep, sleepiness, vigilance and driving performance

The second and third purposes of the present study were to examine whether and how a match between personality (circadian typology) and the shift a taxi driver worked was associated with better work adaptation. Better work adaptation was reflected by better and more sleep, a lower sleepiness level, and better vigilance and driving performance.

Barton and her colleagues proposed and tested a model in which shift system features interacted with individual as well as situational differences to determine shift work adaptation (Barton et al., 1995) (Figure 1). Although the authors claimed that *performance* and health outcomes of shift workers were taken into account in their model, among the various questionnaires used in their study, no measure of actual job performance was taken. In the present study, taxi drivers' performance in vigilance and simulated driving tasks was assessed so as to fill in this knowledge gap and provide empirical evidence for the model of Barton and her colleagues. However, as the present study focused on determining the impact of shift system feature, individual and situational differences, and disturbed sleep on job performance rather than validating the model as a whole, instead of requiring the participants to fill in a large number of questionnaires, only one variable each was selected to represent the characteristics of a shift system, individual differences, and situational differences. The shift system feature investigated was shift (day or night). The individual factor was circadian typology and will be described in this section, while the situational factor was bright light exposure and will be discussed below. Disturbed sleep was conceptualized as a manifestation of disturbed circadian rhythms and reflected by sleep quality and quantity. The outcomes of interest were drivers' performance in a vigilance task and a simulated driving task.

Circadian typology (also known as chronotype and morningness-eveningness) is a personality construct that is closely linked to circadian rhythms and can be reflected physiologically and behaviourally. Physiologically, body temperature peaks about one hour earlier in morning-typed people than in their evening-typed counterparts (Horne & Östberg, 1976). Arousal level decreases from morning to evening in morning-typed people, but increases in evening-typed people (Adan & Guardia, 1993; Mecacci, Scaglione, & Vitrano, 1991). In other words, the morning and evening types are more aroused respectively in the morning and the evening. These arousal patterns are important as they match with performance in various cognitive tasks, e.g. target identification (Hasher & Zacks, 1988), and priming and stop-signal tasks (May & Hasher, 1998). Behaviorally, going to bed and waking up at a later time of the day, having a greater need for sleep, larger sleep debt, and more severe daytime sleepiness, as well as returning to sleep easily in early morning are the characteristics of evening-typed people (Hidalgo, de Souza, Zanette, & Nunes, 2003; Taillard, Philip, Chastang, & Bioulac, 2004). Because of the associations of circadian typology with cognitive performance, sleep habits, and sleepiness, its role in shift work has been studied.

Compared with morning-typed people, evening-typed people have been consistently reported to be more adjusted to shift work (e.g. Bohle & Tilley, 1993; Tankova, Adan, & Buela-Casal, 1994). They were found to have higher sleep quality, regardless of their shorter sleeping time as compared with morning-typed people (Khaleque, 1999). During a night shift, the percentage of workers who reported to be "very sleepy" was higher in morning-typed than evening-typed people (Seo, Matsumoto, Park, Shinkoda, & Noh, 2001).

An important feature of evening-typed people which helps them adjust better to shift work than morning-typed people is their higher flexibility in sleep-wake schedules (Ishihara, Miyasita, Inugami, Fukuda, & Miyata, 1987; Natale, Martoni, & Cicogna, 2003). Evening-typed workers were found to be more likely to sleep during daytime immediately after a night shift, while their morning-typed counterparts were inclined to wait until the night after the night shift before they went to bed (Natale et al., 2003). In addition to the time at which they sleep, the quantity of sleep also differs between circadian types. Breithaupt and his colleagues showed that in response to late bed times (a characteristic of night shift), their morning-typed participants could not compensate by lengthening their sleep in the morning and, therefore, had a reduction in the amount of sleep (Breithaupt, Hildebrandt, Döhre, Josch, & Sieber, 1978). The researchers attributed this to their advanced rhythm of body temperature when compared with evening type participants who had a delayed-phase rhythm and, as a result, were able to continue sleeping in the morning when sleep onset was delayed. The consequence of the shortened sleep duration in the morning-typed participants was their lower ratings of vigilance in the following day.

As a result of the close association between circadian typology and adjustment to shift work, the matching of workers' circadian type with their work schedules has been advocated so that workers can tolerate and adapt better to their shift work (Khaleque, 1999). This is important as adjustment does not seem to improve over time even when night shift is permanent (Åkerstedt, 1990; Eastman, 1990).

In the present study, the need to match taxi drivers' circadian type with the shift they work was investigated. Based on previous findings, it was logical to propose that the morning type and the evening type would be more adjusted to daytime and nighttime work respectively. Indeed, Horne, Brass, and Pettitt (1980) found that in a simulated production-line inspection task, performance in detecting faulty items was the best at about noon for the morning type but at about 20:00 for the evening type, indicating the facilitating effect of a match between circadian typology and work shift. However, according to the model proposed by Barton and her colleagues, shift system features and individual differences directly influence sleep, which, in turn, influence performance (Barton et al., 1995). In addition, a factor that was not shown in the diagram of their model, but was reported to play a significant mediating role in the relationship between disturbed sleep and mood is fatigue. Sleepiness, instead of fatigue, was investigated in the present study because of the extensively reported association between sleepiness and driving performance as well as car accidents, although both sleepiness and fatigue refer to tiredness.

Hence, in the present study, it was hypothesized that shift and circadian type would significantly interact to determine sleep quality and quantity (hypothesis 2). In particular, day shift x morning-typed individuals would have a higher sleep quality and sleep for a longer period of time than night shift x evening-typed individuals who, in turn, would sleep better than the other two combinations of circadian typology and working shift. It was also hypothesized that disturbed sleep would account for vigilance and driving performance both directly and indirectly through sleepiness levels (hypothesis 3).

Bright light exposure

The fourth purpose of the present study was to determine the effectiveness of bright light in improving nighttime drivers' sleep, and thereby reducing their sleepiness levels and improving their vigilance as well as driving performance.

Bright light exposure, which is the situational difference of interest in the present study, is an effective means to treat people with serious problems in their biological rhythm that impair their daily functioning, such as seasonal affective disorder (e.g. Eastman, Young, Fogg, Liu, & Meaden, 1998; Lam, Lee, Tam, Grewal, & Yatham, 2001; Martiny, Simonsen, Lunde, Clemmensen, & Bech, 2004), late luteal phase dysphoric disorder (Lam et al., 1999), insomnia (Campbell, 1998; Campbell, Dawson, & Anderson, 1993; Lack & Wright, 1993), and night-eating syndrome (Friedman, Even, Dardennes, & Guelfi, 2002).

Bright light exposure has also been used to help night-shift workers to adapt to their work (e.g. Costa, Kovacic, Bertoldi, Minors, & Waterhouse, 1997). Dawson, Campbell, and their colleagues conducted a series of studies examining the effectiveness of this intervention. In one study (Dawson & Campbell, 1991), participants were required to work three consecutive 8-hour simulated night shifts and sleep during daytime. In the first night, the treatment group received bright light (6,000 lux) between midnight and 04:00, while the control group received dim light. The researchers found that by the third night shift/day sleep period, the circadian phase shifts of both groups were delayed as shown by their core body temperature, but the delay was significantly larger in the treatment group than the control group (355 minutes vs. 143 minutes). As a result, in the treatment group, the lowest core body temperature occurred during daytime, facilitating the sleep of these participants. This study also demonstrated that the treatment group had less wake time after initial sleep onset; thus, they had a longer total sleep time and a higher sleep efficiency. Furthermore, the alertness level of the treatment group was generally higher and sustained for a longer period of time when they were performing their simulated night work. One of the limitations of this study was that participants only performed a data entry task in their night shifts, and their job performance was not assessed. This limitation was addressed in two other studies conducted by these researchers.

Dawson, Encel, and Lushington (1995) used a similar protocol as in Dawson and Campbell's (1991) study, but this time, participants were exposed to bright light every night during the simulated three-night shift. Compared to the control group, the treatment group performed better in two cognitive psychomotor tasks (verbal reasoning and spatial reasoning). Similar to the findings reported in Dawson and Campbell's (1991) study, this study also showed that the treatment group had a larger delay in circadian phase and a better daytime sleep quality as compared with the control group.

Campbell and Dawson (1990) required their participants to perform a task that simulated the operation of a plant in two consecutive 8-hour night shifts. Participants who were exposed to bright light throughout their second night shift performed better in this operation task and a logical reasoning task than their counterparts who worked in a dimmer lighting condition. Results of this study also showed that the bright light group was able to stay awake for a longer period of time and was less likely to fall asleep during their night shift.

Other studies also documented the effect of bright light in increasing daytime sleep quantity and quality (Kelly et al., 1997; Martin & Eastman, 1998), alleviating nighttime sleepiness (Czeisler et al., 1990; Martin & Eastman, 1998), and improving cognitive and simulated work performance at night (Czeisler et al., 1990; Daurat et al., 1993; Kelly et al., 1997; Thessing, Anch, Muehlbach, Schweitzer, & Walsh, 1994).

In most of the studies referred to above, participants were exposed to bright light for several hours (e.g. Czeisler et al., 1990; Dawson & Campbell, 1991; Martin & Eastman, 1998). This long period of time is not practical for workers, including taxi drivers who are on duty. The effectiveness of *brief* bright light exposure has been reported in three studies, with one involving a single exposure (Åkerstedt, Landström, Byström, Nordström, & Wibom, 2003), and the other two involving repeated exposure (Costa et al., 1993; Leppämäki, Partonen, Piiroinen, Haukka, & Lönnqvist, 2003). In the study of Åkerstedt and his colleagues (2003), 20 students were instructed to sleep for four hours in the night before they went to the laboratory for testing in the following morning. The participants sat on a chair similar to a driver's seat in the laboratory, and they heard normal vehicle noise generated by a sound system. There were three 30-minute sessions, and the participants were first exposed to dim light (5 lux), then bright light (2,000 lux) / red light (30 lux), and finally, dim light (5 lux) again. In each dim light period, the participants viewed a projected picture of a road, while in the light exposure condition, they looked into the light box. The researchers found a reduction in subjective sleepiness from before to after light exposure, with the bright light group demonstrating a greater decrease. However, no such effect on objective sleepiness measured with electroencephalography was found.

The other two studies that assessed the effectiveness of repeated, brief light exposure were field studies and used nurses who were working night shifts as participants (Costa et al., 1993; Leppämäki et al., 2003). They were exposed to bright light (about 2,000-5,000 lux) for 20 minutes every two hours and altogether, four times in each night shift. Leppämäki and colleagues (2003) found improvement in the participants' subjective evaluation of their well-being during and after the night shifts when bright light was used. In the study of Costa and colleagues (1993), when exposed to bright light, nurses felt less anxious and tired but more energetic, and showed better performance in a cognitive task.

Because of these well documented beneficial effects of repeated, brief bright light exposure, the present study investigated whether bright light would also help nighttime taxi drivers to adapt to their work. In fact, bright light exposure can be regarded as a situational factor in the model proposed by Barton and her colleagues (1995) since it has been found to be effective in simultaneously altering circadian rhythms and improving sleep quality and quantity (Dawson & Campbell, 1991; Dawson et al., 1995; Lack & Wright, 1993).

With regard to the relationship among sleep, sleepiness and performance in Barton's theoretical model, it was hypothesized that bright light would be effective in improving the sleep quality and quantity of nighttime drivers. It was also hypothesized that bright light would be effective in reducing nighttime drivers' deterioration in alertness as well as vigilance and driving performance (hypothesis 4).

Overview of the present study

Sleepiness has been consistently found to be common in drivers in foreign countries, and its detrimental effects on vigilance and driving performance are well documented. However, naturalistic studies are limited, and this important health problem has not been studied in Hong Kong. In the present study, a group of professional drivers, specifically taxi drivers, served as the participants since local statistics revealed their higher vulnerability to traffic accidents, and they were tested in a naturalistic environment. The objectives of the present study were to (1) examine how the sleepiness as well as vigilance and driving performance of taxi drivers vary within one shift and whether these changes would be greater among daytime or nighttime drivers, (2) investigate whether a match between circadian typology and shift would be associated with better sleep and longer sleep time, (3) examine the mediating role of sleepiness between disturbed sleep and performance, and (4) determine the effectiveness of bright light exposure in helping nighttime taxi drivers to have better and more sleep, and to maintain their alertness and performance over a shift.

CHAPTER 2

Main Study

Method

Recruitment and Characteristics of Participants

There are three kinds of taxis in Hong Kong, which work in different areas – urban and rural areas, as well as an outlying island. However, urban taxis contribute 84.1% of the total number of taxis (Transport Department, 2004b). Hence, only this major kind was included in the present study.

Sixteen daytime and sixteen nighttime taxi drivers were recruited from a sample of drivers who had been screened for their circadian type in advance. In the first day / night (both daytime and nighttime drivers) and the third day / night (nighttime drivers only), drivers were paid HK$80 for their participation in each of the three test periods, and at the end of the last test period, a HK$60 bonus was given if the drivers were punctual for all the test periods. In the second day / night (nighttime drivers only) which consisted of longer test periods, drivers were paid HK$100 for their participation in each of the three test periods, and at the end of the last test period, a HK$150 bonus was given for punctuality.

Procedure

One hundred and eleven drivers (56 daytime and 55 nighttime) were recruited from three taxi stands (one on Hong Kong Island, one in Kowloon, and one in the New Territories). They were first screened for their circadian type. They were interviewed by two trained interviewers using the Morningness-Eveningness Questionnaire (Horne & Östberg, 1976). Demographic information, e.g. age and years of working day / night shift, was also collected. At the end of the interview, the participants were asked whether they would like to participate in a future experimental study. The questionnaire used in the interviews is presented in Appendix 1. Each interview took about ten minutes to complete. Each of the participants was paid $20 for the interview.

The drivers were categorized into three types according to the cutoff points reported in a recent study (Taillard et al., 2004) (Table 2). This set of cutoff points were used because they were developed using a middle-aged population, and taxi drivers form a middle-aged population. Drivers who indicated during the interview that they would like to participate in the experimental study were randomly selected so that the final sample of the experiment was expected to consist of eight morning-typed and eight evening-typed drivers of each shift. However, this was not possible because there was an uneven distribution of morning-typed and evening-typed people in the daytime and nighttime driver samples.

Upon agreeing to participate, the drivers discussed with the experimenter about the date for data collection. Every daytime driver was tested for one day, whereas every nighttime driver was tested for three consecutive nights. Each day / night comprised three test periods. The drivers were required to arrive at the site at the beginning, in the middle, and at the end of a shift. Between test periods, the drivers were free to pick up customers as usual. Drivers performed their tests in their taxi, which was parked at the Kowloon MTR station. This site was chosen because it was located in a busy area where plenty of customers were available during daytime and at night. Thus, this helped reduce the chance that the taxi drivers would refuse to come for the repeated testing.

When the drivers arrived at the site on the first day / night, they were required to sign a consent form which stated that financial compensation would be given at the end of each test period, and that they could terminate their participation any time but still receive the compensation for that period. Strict confidentiality was also guaranteed. The participants were first asked to report the quality and quantity of sleep in their last major sleep period. Then, they rated their current sleepiness level and reported the countermeasures they had used to fight against sleepiness since they started working that day. The participants then practiced on the vigilance and simulated driving tasks so as to minimize any practice effect in subsequent test periods.

These tasks were presented on a Wintel notebook computer with a 15-inch colour monitor. The computer was placed in front of the participants while they sat comfortably in their taxi cabin. The notebook computer was connected to an acceleration pedal and a braking pedal. When the participants were familiar with the tasks, real testing began. In subsequent test periods, similar procedures were repeated: prior to the vigilance and the simulated driving tasks, the drivers reported their level of sleepiness and any sleepiness countermeasures they had used since the previous test period. Each test period lasted for about 30 minutes. The presentation of the vigilance and the simulated driving tasks was counterbalanced in order to minimize any carryover effects.

For nighttime drivers, in the second and the third nights, similar procedures were carried out, but bright light exposure was administered in the second night. In each of the three test periods that night, drivers were first exposed to bright light for 15 minutes prior to their self-report of sleepiness and the administration of the vigilance and driving tasks.

During light exposure, a light source was placed about 50 cm away from the participants. Instructions were given to the participants so that they remained in their seat and read magazines or newspapers while trying to let their eyes be exposed to the maximum amount of light, since it was found that the amount of light perceived by the participants would be significantly reduced with increasing distance and time spent looking elsewhere (Dawson & Campbell, 1990). Light intensity was measured every five minutes during the 15-minute exposure.

Instruments

In Hong Kong, many taxi drivers are not Chinese-English bilingual. Therefore, the scales used in the present study were first translated to Chinese and then back-translated. The Chinese versions were administered during screening and in the experiment.

<u>Circadian typology.</u> The 19-item Morningness-Eveningness Questionnaire (Horne & Östberg, 1976) was used in the screening to assess the participants' morningness-eveningness preference. On five of the items, the participants were provided with a time scale on which they indicated their preferred working, rising and bedtimes, their usual bedtime, and the time they "feel best". On each of the other items, four options were given, and the participants were required to choose the answer that described them best. A composite score was computed to determine the Morningness / Eveningness of the participants. This scale has been found to have adequate validity (Adan, 1993; Horne & Östberg, 1976; Taillard et al., 2004) and reliability (Adan, 1993).

<u>Sleep quantity and quality.</u> Participants' sleep quality and quantity were assessed by items from the Pittsburgh Sleep Quality Inventory (Buysse, Reynolds, Monk, Berman, & Kupfer, 1989). This inventory was originally designed to measure sleep quality and disturbances in the previous month. However, in the present study, only the subjective evaluation of participants in how well and how much they had slept in their last major sleep period were important, so only two items were used and

modified to satisfy this purpose. Participants were required to rate their sleep quality from "1" (representing "very good") to "4" (representing "very bad") in response to the statement "in your last sleep (not nap), how would you rate your sleep quality?". This item was recoded so that the higher the score, the better their sleep. The participants also needed to report their sleep quantity in the item "in your last sleep (not nap), how many hours of sleep did you get?".

Sleepiness. Participants were required to rate their sleepiness level from "1" (representing "feeling active and vital; alert; wide awake") to "7" (representing "almost in reverie, sleep onset soon; lost struggle to remain awake") on the Stanford Sleepiness Scale (Hoddes, Zarcone, Smythe, Phillips, & Dement, 1973). This scale has been found to be sensitive to sleep deprivation (Hoddes et al., 1973), and correlate well with objective and subjective measures of sleepiness (Johnson, Freeman, Spinweber, & Gomez, 1991; Pilcher, Pury, & Muth, 2003).

Countermeasures. Participants were required to indicate whether they had adopted certain coping strategies to fight sleepiness. If they had, they were also required to indicate the number of times they used that strategy. The strategies were extracted from two previous research studies, which examined the frequency of usage and effectiveness of various strategies (Oron-Gilad & Shinar, 2000; Verwey & Zaidel, 1999). The items included in the present study are listed in Appendix 2. The item, using radio to chat with colleagues, was not included in previous studies, but was added in the present study because this is a common practice among Hong Kong taxi drivers. An open-ended question in which participants could report other strategies they might have used was also included.

Vigilance task. The A-X version of the Continuous Performance Task (CPT), was adopted to assess the participants' vigilance level. The task was similar to that used in a previous study (Halperin, Sharma, Greenblatt, & Schwartz, 1991); however, considering the education level of taxi drivers, English letters were replaced by digits (0-9). The digits (1.5 cm x 1 cm wide) were presented between two permanent black vertical bars (1 cm high x 0.5 cm wide) on the computer monitor for 200 ms each, one after another against a grey background. The interstimulus interval was 1.5 s. The participants were instructed to step onto the acceleration pedal throughout the task, but when a "9" appeared immediately after a "1", they were required to react by releasing the acceleration pedal and stepping onto the braking pedal. Four blocks, each with 100 digits, were presented in each test period. In every block, the target sequence ("1-9") was presented 10 times, while 17 "1's" were not followed by a "9", and five "9's" were not preceded by a "1". The CPT A-X task has been reported to have adequate reliability and validity (Halperin et al., 1991). This task took about twelve minutes to complete. The hit reaction time was recorded. Errors were categorized into omission errors (not responding to a "1-9" sequence) and commission errors (the total of 1-not 9, 1-only, 9-only, and random errors). The mean of each measure across the four blocks in every test period was used for subsequent analyses.

<u>Simulated driving task.</u> A simulated driving task, which was designed to maximize its relevance to real-life driving conditions, was used to assess the driving performance of the participants in each test period. Before the task began, participants placed their right foot on the acceleration pedal. When they were ready, they initiated the program by pressing a button on the computer keyboard. Participants then saw a flowing view as if they were driving their taxi at 80 km/h on a monotonous road. The view froze, i.e. their taxi stopped, every time they stepped onto the braking pedal. The view started flowing again automatically after three seconds. The task lasted for about ten minutes.

In this task, the participants saw two kinds of stimuli, traffic lights and pedestrians, which were presented in a random order with a mean interstimulus interval of 15 seconds and a range of 10-20 seconds. During the "journey", the participants encountered a total of twenty traffic lights, one at a time (Figure 2). Ten of them remained green all the time, while the other ten changed from green to red. The participants were instructed to step onto the braking pedal *only* when the light changed from green to red. The number of times they stepped onto the braking pedal when the light remained green and when no traffic light appeared (false alarm) was recorded. Also, the number of times they failed to respond when the light changed colour (miss) was recorded. Furthermore, when they reacted correctly (hits), their reaction time (starting from the appearance of the red light) was recorded.

Apart from the twenty traffic lights, twenty pedestrians also appeared on the screen, one at a time. Ten pedestrians appeared and stayed on the sidewalk (Figure 3a), while the other ten walked from the sidewalk to the driving lane (Figure 3b). The participants were required to step onto the braking pedal *only* in the latter condition. The number of times they reacted when the pedestrian remained on the sidewalk and when no pedestrian appeared (false alarm) was recorded. Also, the number of times they failed to respond when the pedestrian walked to the driving lane (miss) was recorded. Furthermore, when they responded correctly (hits), the reaction time (starting from the time the pedestrian walked to the driving lane) was recorded.

Bright light and its intensity. A light source (Apollo Brite Lite V) was used. It emits 10,000 lux full spectrum light. Ten thousand lux is comparable to the intensity experienced under sunlight just after dawn. However, as mentioned previously, light intensity varies depending on the distance from the light source (Dawson & Campbell, 1990). The actual amount of light that each participant received was measured with a photometer (Konica Minolta Auto Meter VF with a flat diffuser) placed at eye level of the participants. The mean of the light intensity measures taken at the beginning, at the fifth minute, and at the tenth minute of the 15-minute exposure period was calculated and was used to indicate the light intensity at which the participants were exposed to during that test period. The intensities were then averaged across the three exposure periods.

CHAPTER 3

Results

The mean age of the screening sample was 49.78 (SD = 8.40). Among the 56 daytime taxi drivers, 18, 30, and 8 were categorized into the morning type, the neither type, and the evening type respectively (Table 2). Among the 55 nighttime taxi drivers, 1, 10, and 44 were categorized into the morning type, the neither type, and the evening type respectively.

The mean age of the daytime drivers and the nighttime drivers in the experimental sample was 46.19 (SD = 5.61) and 49.34 (SD = 10.54) respectively, and these two groups did not significantly differ in age ($t = 1.06, p > .05$). The daytime drivers and the nighttime drivers on average worked their current shift for 10.56 years (SD = 7.94 years) and 14.56 years (SD = 7.16 years) respectively, and these two groups did not significantly differ in their driving experience ($t = 1.50, p > .05$). Among the sixteen daytime taxi drivers, fourteen of them were categorized as morning type, while only one was neither type, and one was evening type (Table 2). Among the sixteen nighttime taxi drivers, eight were categorized as evening type, and eight were neither type. None of them were morning type.

The descriptive statistics for sleep quality and quantity, sleepiness, performance in the vigilance and simulated driving tasks of both daytime and nighttime drivers are shown in Table 3.

Since the correlations between the quantity of each countermeasure and sleepiness as well as performance were not significant, countermeasures were not used as covariates in subsequent analyses.

Hypothesis 1

Repeated measures ANOVAs on day / night 1 data were used to determine whether driver sleepiness and their performance in the vigilance and the simulated driving tasks deteriorated with increasing hours of driving, and whether nighttime taxi drivers were more impaired in their alertness and performance than their daytime counterparts.

Sleepiness

Daytime and nighttime taxi drivers did not differ in their levels of sleepiness ($F(1,30) = .53, p > .05$) (Table 4). However, participant's sleepiness levels significantly increased throughout a shift ($F(2,60) = 8.60, p < .05, \varepsilon = .73$). Post hoc paired-samples t tests were conducted. Participants' level of sleepiness was significantly higher at the middle and end of a shift as compared with the beginning ($t(31) = 2.81, p < .017$; $t(31) = 3.167, p < .017$ respectively), but no significant difference was found between the middle and end of the shift ($t(31) = 2.27, p > .017$). Time and the participant's work shift did not interact to determine their sleepiness levels ($F(2,60) = 1.40, p > .05, \varepsilon = .73$).

Continuous Performance Test

Reaction time as well as the numbers of omission and commission errors did not differ between daytime and nighttime drivers ($F(1,30) = 1.27, p > .05$; $F(1,30) = .01, p > .05$; $F(1,30) = .48, p > .05$ respectively) (Table 4). Also, reaction time and the number of omission errors did not change over time, but the number of commission errors decreased within a shift ($F(2,60) = 5.27, p < .05, \varepsilon = .79$). The results of post hoc analyses with paired-samples t tests showed that the participants made more commission errors at the beginning of the shift as compared with that at the end ($t(31) = 2.58, p < .017$), but the number of commission errors at the middle did not differ from those at the beginning or end of the shift ($t(31) = 2.24, p > .017$; $t(31) = 1.37, p > .017$ respectively). There was no significant interaction between shift and time on reaction time, the number of omission errors, or the number of commission errors ($F(2,60) = 1.15, p > .05$; $F(2,60) = 1.28, p > .05$; $F(2,60) = .55, p > .05, \varepsilon = .79$ respectively).

Simulated driving task

For the traffic light stimuli, daytime and nighttime drivers did not differ in their reaction time ($F(1,30) = .13, p > .05$) (Table 4). However, reaction time decreased over time ($F(2,60) = 12.82, p < .05$). Results of post hoc paired-samples t tests indicated that participants reacted more slowly at the beginning as compared with that at the middle and end of the shift ($t(31) = 4.30, p < .017$; $t(31) = 4.01, p < .017$ respectively), but their reaction time at the middle and end of the shift did not differ ($t(31) = .72, p > .017$). No significant interaction between shift and time was found ($F(2,60) = .31, p > .05$). The number of misses and false alarms did not differ between the daytime and the nighttime drivers ($F(1,30) = 1.54, p > .05$; $F(1,30) = 1.63, p > .05$ respectively), and they did not change within the shift ($F(2,60) = .70, p > .05$; $F(2,60) = .91, p > .05$ respectively). Moreover, there was no significant interaction between shift and time ($F(2,60) = .29, p > .05$; $F(2,60) = .49, p > .05$ respectively).

For the pedestrian stimuli, reaction time as well as the numbers of misses and false alarms did not differ between daytime and nighttime drivers ($F(1,30) = .25, p > .05$; $F(1,30) = 4.01, p > .05$; $F(1,30) = .01, p > .05$ respectively), and they did not significantly change throughout a shift ($F(2,60) = .70, p > .05$; $F(2,60) = 2.63, p > .05, \varepsilon = .87$; $F(2,60) = 2.14, p > .05, \varepsilon = .69$ respectively). Furthermore, no significant time x shift interaction was observed ($F(2,60) = 2.20, p > .05$; $F(2,60) = .76, p > .05, \varepsilon = .87$; $F(2,60) = .39, p > .05, \varepsilon = .69$ respectively).

Hypothesis 2

It was originally proposed that ANOVA would be used to investigate whether circadian typology interacted with shift to influence sleep quality and quantity. However, as there was no morning-typed nighttime driver and only one evening-typed daytime driver in the experimental sample, this statistical analysis was not possible. Instead, correlational analyses between the morningness-eveningness score and sleep quality as well as sleep quantity prior to the first test period were conducted for each shift.

For daytime drivers, the correlation between morningness-eveningness score and sleep quality was significant ($r = -.60, p < .05$), indicating that the more morning-typed these participants were, the better their sleep was. However, the correlation between morningness-eveningness score and sleep quantity was not significant ($r = .14, p > .05$).

For nighttime drivers, the correlation between the morningness-eveningness score and sleep quality was moderate though not significant ($r = .23, p > .05$). The correlation between the morningness-eveningness score and sleep quantity was not significant ($r = -.04, p > .05$).

Hypothesis 3

Hierarchical regression was used to examine the hypothesized mediating role of sleepiness in the relationship between disturbed sleep and vigilance and driving performance. However, according to Baron and Kenny (1986), a predictor variable should be significantly correlated with the potential mediator and a criteron variable to support any mediation effect. As demonstrated in Table 5, the quantity of sleep prior to day / night 1 testing was significantly correlated with sleepiness during test period 1 ($r = -.38, p < .05$), but not test period 2 or 3 ($r = -.13, p > .05$; $r = .27, p > .05$ respectively). In addition, since the sleepiness level measured with the Stanford Sleepiness Scale is acute rather than chronic, only those correlations between sleepiness and vigilance and driving performance variables within the same test period are meaningful. Therefore, only those data collected in test period 1 were considered. Sleep quantity only had a significant correlation with the number of commission errors of the vigilance task ($r = -.43, p < .05$), so a hierarchical regression with sleep quantity and sleepiness entered into blocks 1 and 2 respectively was conducted to examine the mediating role of sleepiness. Results are shown in Table 6. The mediating effect of sleepiness was not significant ($\Delta R^2 = .03, \Delta F(2,29) = .96, p > .05$).

Hypothesis 4

The mean bright light intensity of the sixteen nighttime drivers was 3053.79 lux (SD = 1596.27 lux). Repeated measures ANOVAs with light intensity as a covariate were conducted to determine the effects of bright light on improving sleep and alleviating the deterioration in alertness as well as vigilance and driving performance throughout a shift.

<u>Sleep quality and quantity</u>

To determine the effect of bright light exposure on sleep, comparisons were based on the sleep quality and quantity the participants reported in night 2 (before exposure) and night 3 (after exposure). As shown in Table 7, results of repeated measures ANOVAs showed that both sleep quality and quantity did not improve after bright light exposure ($F(1,14) = 1.91, p > .05$; $F(1,14) = .61, p > .05$ respectively).

A series of 3 x 3 repeated measures ANOVAs with treatment and time as the independent variables were conducted to determine the effect of bright light on changes in drivers' sleepiness levels, vigilance and driving performance throughout a shift. Results are summarized in Table 7.

<u>Sleepiness</u>

As shown in Table 7, participants' sleepiness levels were not lowered after bright light exposure ($F(2,28) = 2.08, p > .05$). However, sleepiness increased throughout a shift ($F(2,28) = 12.36, p < .05$). Results of post hoc repeated measures ANOVAs on the mean sleepiness level in each test period across the three nights with light intensity as a covariate showed that compared to the end of a shift, sleepiness was significantly lower at the beginning and middle ($F(1,14) = 17.97, p < .017$; $F(1, 14) = 10.39, p < .017$ respectively), but sleepiness did not differ between the beginning and middle of a shift ($F(1,14) = 5.25, p > .017$). There was no significant treatment x time interaction on sleepiness ($F(4,56) = .67, p > .05, \varepsilon = .88$).

<u>Continuous Performance Test</u>

Bright light had an effect on reaction time ($F(2,28) = 5.85, p < .05$) (Table 7). Post hoc repeated measures ANOVAs using the mean reaction time across the three test periods of each night as the dependent variable and light intensity as a covariate were conducted, and it was found that participants responded more slowly in night 2 than in night 1 ($F(1,14) = 9.37, p < .017$), showing an immediate impairing effect of bright light on reaction time. However, no prolonged effect was found as reaction time did not differ between nights 1 and 3 ($F(1,14) = 6.47, p > .017$). Also, no significant difference in reaction time was found between nights 2 and 3 ($F(1,14) = .003, p > .017$). In addition, reaction time increased throughout a shift ($F(2,28) = 4.53, p < .05$). Results of post hoc repeated measures ANOVAs on the mean reaction time in each test period across the three nights with light intensity as a covariate showed that compared to the beginning of a shift, participants reacted significantly more slowly at the end ($F(1,14) = 6.77, p = .017$), but reaction time at the middle did not differ from that at the beginning or end of a shift ($F(1,14) = .55, p > .017$; $F(1,14) = 6.13, p > .017$ respectively). There was no significant interaction between treatment and time ($F(4,56) = 1.27, p > .05, \varepsilon = .89$).

The numbers of omission and commission errors did not change after bright light exposure ($F(2,28) = .49, p > .05$; $F(2,28) = .32, p > .05, \varepsilon = .71$ respectively), and they did not significantly change throughout a shift ($F(2,28) = 1.38, p > .05$; $F(2,28) = .07, p > .05$ respectively). Furthermore, no significant treatment x time interaction effect was found on the numbers of omission and commission errors ($F(4,56) = .74, p > .05$; $F(4,56) = .16, p > .05, \varepsilon = .53$ respectively).

Simulated driving task

As summarized in Table 7, for the traffic light stimuli, reaction time and the numbers of misses and false alarms did not change after bright light exposure ($F(2,28) = .32, p > .05$; $F(2,28) = .12, p > .05$; $F(2,28) = .06, p > .05, \varepsilon = .80$ respectively). Also, reaction time and the number of false alarms did not change throughout a shift ($F(2,28) = .92, p > .05$; $F(2,28) = 2.71, p > .05$ respectively), but the number of misses changed over time ($F(2,28) = 4.76, p < .05$). No significant interaction between treatment and time was observed on either mean reaction time or the number of false alarms ($F(4,56) = .57, p > .05$; $F(4,56) = 1.49, p > .05, \varepsilon = .37$ respectively). But the treatment x time interaction on the number of misses was significant, indicating that the change in the number of misses throughout a shift differed after bright light exposure ($F(4,56) = 2.70, p < .05$). A post hoc repeated measures ANOVA with light intensity as a covariate was conducted for each night, and results showed that the number of missed traffic lights changed significantly over time in night 2 ($F(2,28) = 5.06, p < .017$), but not in nights 1 and 3 ($F(2,28) = 1.94, p > .017$; $F(2,28) = 1.59, p > .017$ respectively). Results of further post hoc analyses with repeated measures ANOVAs demonstrated that in night 2, participants tended to miss more traffic lights at the end as compared with at the beginning of the shift ($F(1,14) =$

6.71, $p = .021$), showing an immediate impairing effect of bright light. The number of missed traffic lights at the middle of the shift did not differ from that at the beginning and end ($F(1,14) = 2.33$, $p > .017$; $F(1,14) = 4.24$, $p > .017$ respectively).

For the pedestrian stimuli, reaction time, the numbers of misses and false alarms did not change after bright light exposure ($F(2,28) = .50$, $p > .05$; $F(2,28) = 1.15$, $p > .05$, $\varepsilon = .73$; $F(2,28) = 4.05$, $p > .05$, $\varepsilon = .66$ respectively), and they also did not change throughout a shift ($F(2,28) = .33$, $p > .05$; $F(2,28) = .88$, $p > .05$; $F(2,28) = 2.67$, $p > .05$, $\varepsilon = .73$ respectively). In addition, the interaction between treatment and time was not significant on mean reaction time, the numbers of misses and false alarms ($F(4,56) = 1.95$, $p > .05$; $F(4,56) = 1.53$, $p > .05$; $F(4,56) = 2.35$, $p > .05$, $\varepsilon = .44$ respectively).

CHAPTER 4

Discussion

The present study aimed at (1) comparing the changes in sleepiness as well as vigilance and driving performance throughout a shift between daytime and nighttime taxi drivers, (2) determining whether matching drivers' shift and their circadian type improved their sleep quality and quantity, (3) examining the mediating effect of sleepiness between disturbed sleep and vigilance and driving performance, and (4) investigating the effectiveness of bright light in improving sleep and alleviating the deterioration of drivers' alertness and performance over time.

Hypothesis 1

The sleepiness level of taxi drivers was found to increase significantly from the beginning to the middle of the shift and remain steady from the middle to the end of a shift. However, as reflected by the decrease in the number of commission errors, the drivers' performance in the vigilance task improved from the beginning to the end of a shift. Also, as shown by the decrease in reaction time, performance in the simulated driving task also improved throughout a shift. Both the daytime and the nighttime drivers showed the same pattern of increasing sleepiness and improving performance. Therefore, hypothesis 1 was only partially supported.

These changes over a shift seem to be contradictory, but this can be explained by the possible effort of the drivers to stay alert, their professional experiences, and self-selection process, as well as practice effect. Previous research showed that in a prolonged drive, participants' blink frequency increased throughout the testing, suggesting an attempt to remain alert when they felt tired (Summala et al., 1999). This explanation may be particularly applicable to experienced professional drivers such as those in the present study, since they would have given up their job if they failed to cope with the increasing sleepiness resulted from prolonged driving. Thus, a self-selection process is likely to operate in the professional driver population, and it helps retain drivers who are vigilant and have the ability to maintain adequate driving performance when they feel sleepy. This can be indirectly reflected by the uneven distribution of circadian types in the daytime and nighttime driver sample screened: daytime drivers consisted of a larger proportion of morning-typed people than evening-typed people, while nighttime drivers consisted of a larger proportion of evening-typed people than morning-typed people. This pattern implies that those drivers who have a mismatch between their circadian type and their work shift are highly likely to have quit their job or changed shifts.

The contradictory results can also be explained by practice effects. As the participants were exposed to the same cognitive tasks repeatedly, the tasks became easier over time, and this reduction in difficulty might compensate for the increase in their sleepiness levels.

Hypothesis 2

Due to the uneven distribution of circadian type in the experimental sample, the benefit of matching shift and circadian type could not be statistically examined as originally proposed. However, the possible advantage of this match could be demonstrated by the finding that for daytime drivers, the more morning-typed they were, the higher sleep quality they had. For nighttime drivers, a similar trend was found between high eveningness and higher sleep quality. Therefore, for both daytime and nighttime drivers, it is possible that a match between their shift and their circadian type is associated with a higher sleep quality, and further studies are needed to provide additional empirical evidence.

Hypothesis 3

Contrary to the hypothesis, sleepiness was not found to mediate the relationship between disturbed sleep and vigilance and driving performance. The present study also showed that the majority of the relationships among sleep, sleepiness, and performance were weak. Therefore, the validity of including performance in the model of Barton and her colleagues (1995) is suspect. However, given that the relationships among sleep quantity, sleepiness level, and vigilance performance were actually moderate and the sample size in the present experiment was rather small, further empirical studies are necessary in order to conclude that job performance was not influenced by disturbed sleep.

Hypothesis 4

Contrary to the hypothesis, the present study showed that repeated, brief bright light exposure was not effective in helping nighttime taxi drivers to adapt to their work. It even had immediate negative effects on their work adaptation. More specifically, bright light was found to have an immediate impairing effect on vigilance task performance by lengthening drivers' reaction time. Also, immediately after being exposed to bright light, the drivers tended to miss an increasing number of traffic light stimuli over time in the simulated driving task, while this trend was not observed before exposure.

These findings contradicted with those of previous studies which demonstrated the beneficial effects of repeated, brief bright light exposure, and this was probably because of the differences in the length of the bright light exposure period, the working environment, the driving task used, and the extent of self-selection process. In the two past studies which examined the effectiveness of repeated, brief light exposure (Costa et al., 1993; Leppämäki et al., 2003), participants received bright light for a total of 80 minutes within a shift (a 20-minute exposure period every two hours). However, in the present study, nighttime drivers were exposed to bright light for 15 minutes every 4-5 hours and altogether, three times in the treatment night. As a result, the exposure period was about half of that used in previous research. This implies that the length of exposure period was critical in the effects of repeated, brief bright light: a short total period of exposure may actually impair adaptation to shift work, while a long total period of exposure can lead to lower ratings of sleepiness and better cognitive performance. Further empirical studies are needed to determine the minimum length of exposure at which the beneficial effects of bright light in improving sleep, alertness, and performance are obtained.

Another explanation for the findings of the present study is that the working environment of taxi drivers was different from that of the previously used samples (nurses). According to Costa and her colleagues (1993), in hospital, light was usually turned off at night, but nurses were provided with desk lamp. However, nighttime taxi drivers work in their dark cabin throughout their shift although they occasionally drive their passengers to brightly lit places. Therefore, continuous exposure to light such as that in hospital seems to determine the effect of bright light in shift work adaptation, and bright light should not be used on people who are accustomed to working in the dark; otherwise, there are more impairing than beneficial effects.

The different driving tasks used might also contribute to the different results obtained. In the study of Åkerstedt and his colleagues (2003), the student "driver" participants did not need to perform any driving task, such as driving in a simulator or on the site, in order to simulate the typical work of a professional driver, so the cognitive demand on these participants was much lower and bright light was found to be effective in reducing subjective sleepiness. In the present study, nighttime taxi drivers worked a 12-hour shift, and prolonged continuous driving might impose a much larger cognitive demand on them. As a result, bright light was not effective enough to eliminate the impact of this demand, thereby failing to reduce the sleepiness levels of nighttime taxi drivers.

Finally, nighttime taxi drivers work permanent night shift, while nurses in the study of Costa and her colleagues (1993) worked rotating shifts, and self-selection processes may operate to different extents in these professions. The nurses had two rest days after night shifts in which they might replenish. However, nighttime taxi drivers work six to seven nights a week. Therefore, the demand on the driving profession is larger, and if nighttime taxi drivers cannot adapt well, they are more likely to quit or change shift. As mentioned previously, the self-selection process is likely to operate in the driving profession. The self-selection process may be particularly intense in nighttime taxi drivers as they form an older population than the nursing profession and older people tend to be more morning-typed.

A limitation of the present study is that the sample size is quite small, so caution should be taken when interpreting the results, particularly those regarding the effects of bright light. Further studies are needed in order to provide further empirical support for the negative effects of repeated, *very* brief bright light, especially for nightshift workers who always work in a dark environment.

In conclusion, the present study has both theoretical and practical significance. It showed that job performance should not be included in the model proposed by Barton and her colleagues (1995), since self-selection processes may operate in professions that require shift work. Those workers who cannot adapt to their work adequately may be eliminated. This study also demonstrated that matching work shift and circadian typology may be associated with better sleep. Finally, the present study pointed out that not only was *very* brief bright light exposure unable to help adaptation to night work, but it actually impaired the performance of permanent night shift workers who work in the dark most of the time.

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Figure 1 The model proposed by Barton and her colleagues (1995)

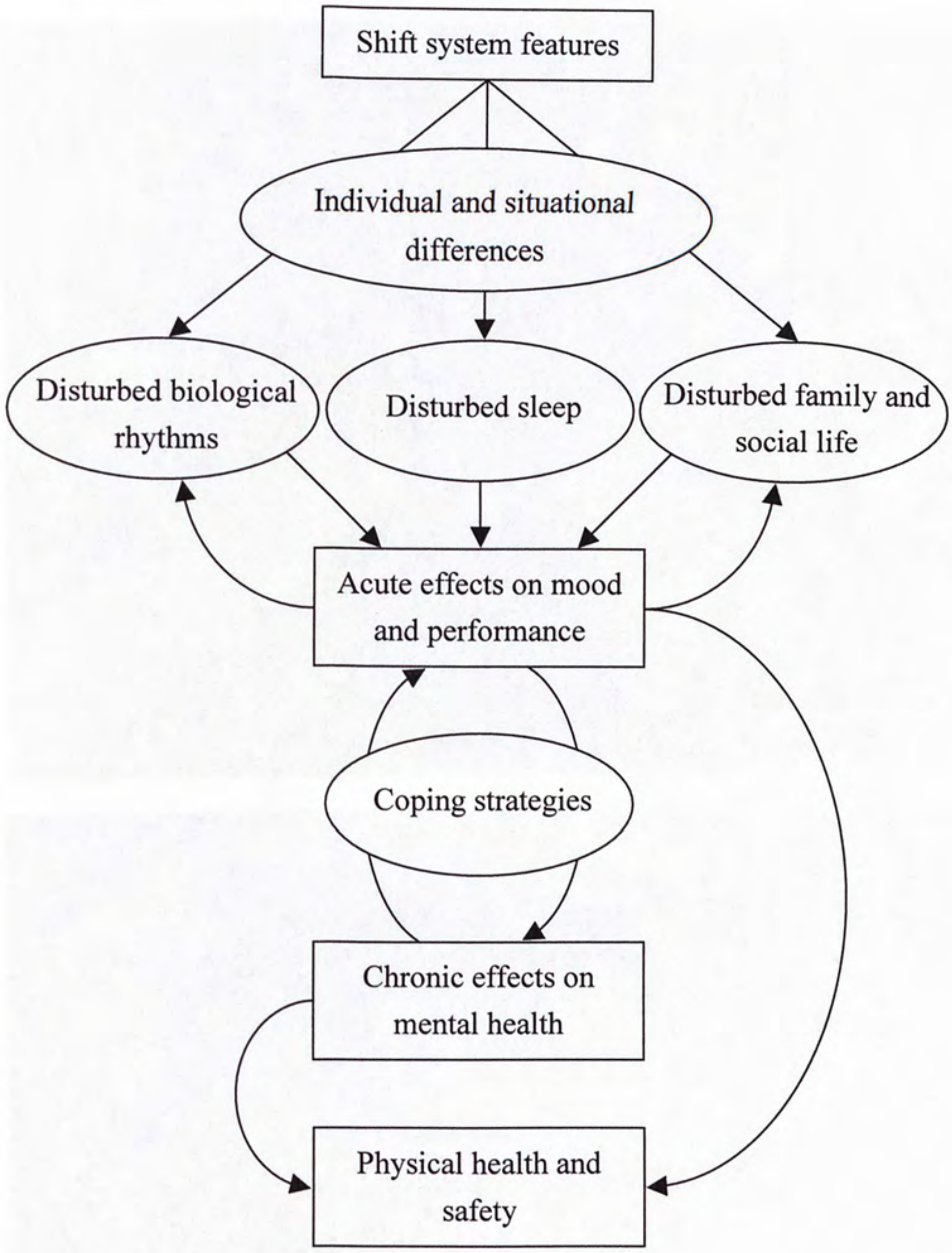

Figure 2 Screen shots in the simulated driving task with traffic light as the stimulus:

(a) red light and (b) green light

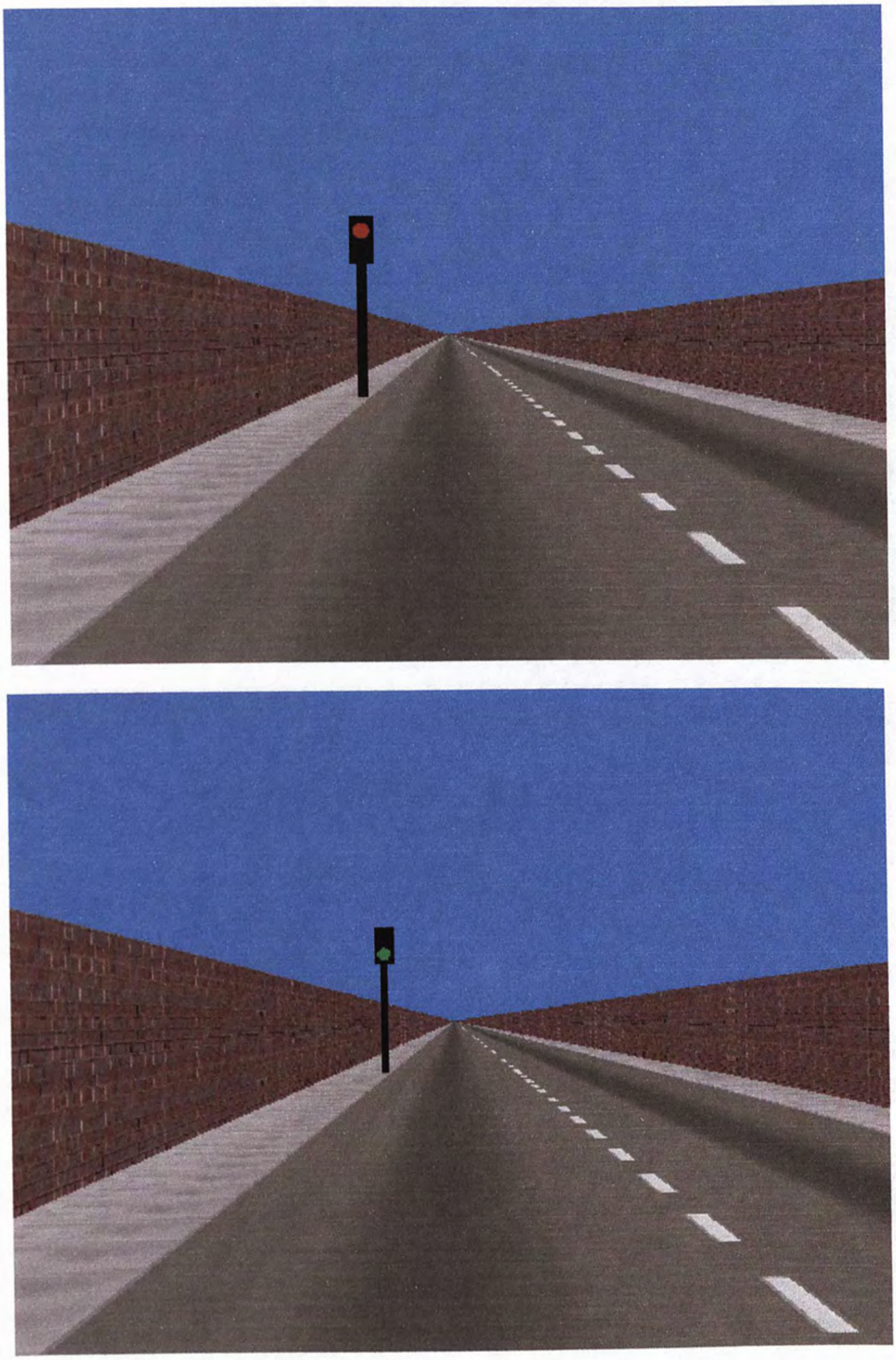

Figure 3 Screen shots in the simulated driving task with pedestrian as the stimulus: (a) pedestrian on the sidewalk and (b) pedestrian on the driving lane

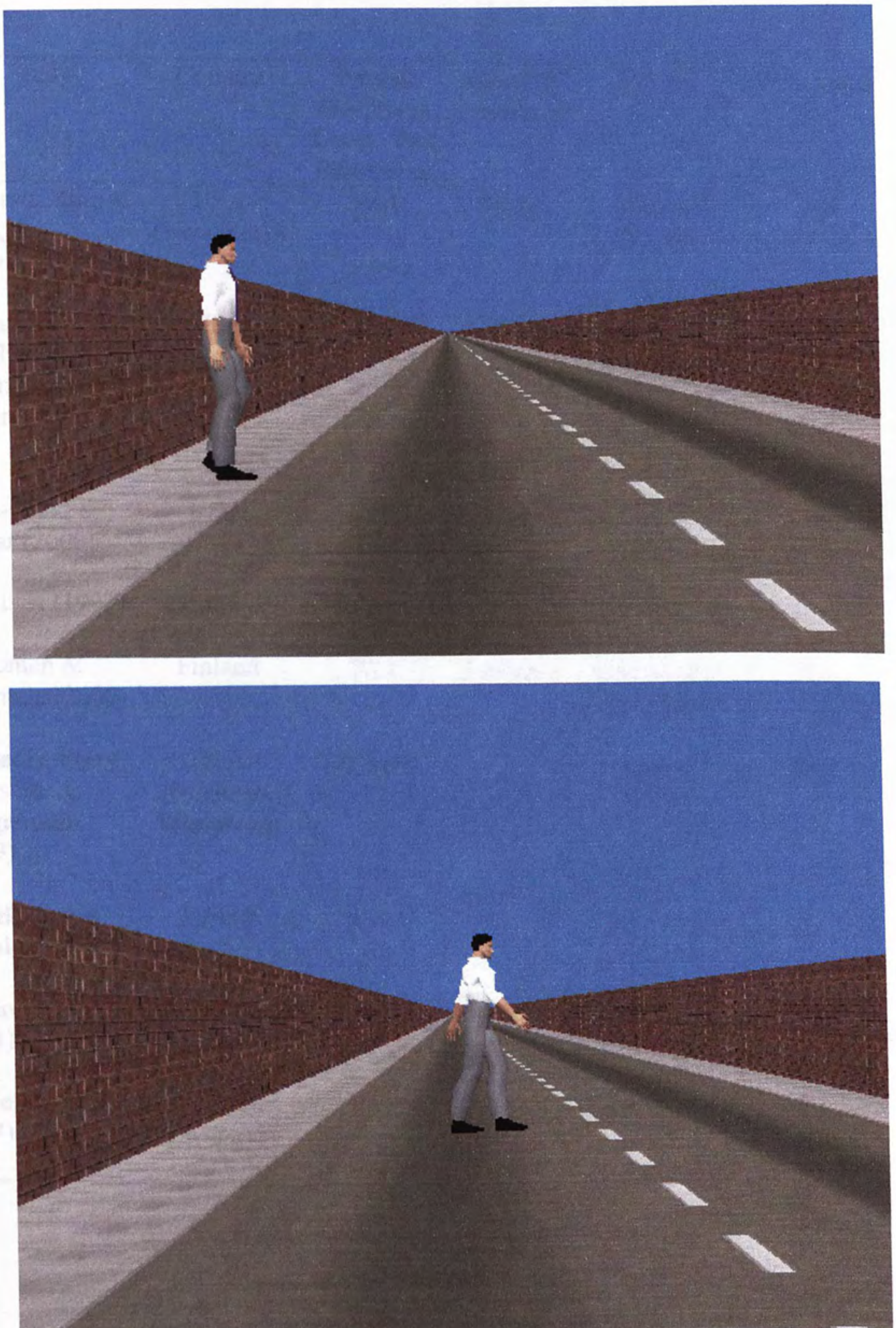

Table 1 Prevalence and criteria of driver sleepiness, and the sample involved in different countries

Study	Country	Present Sleepiness Level / Past Experience	Duration considered	Sample	Prevalence
McCartt, Ribner, Pack, & Hammer (1996)	USA (New York)	Past	1 year	Licensed drivers	54.6
McCartt, Rohrbaugh, Hammer, & Fuller (2000)	USA (New York)	Past	Lifetime	Long-distance truck drivers	47.1
			1 year		25.4
Oron-Gilad & Shinar (2000)	Israel	Past	1 year	Military truck drivers	39
Corfitsen (1993)	Denmark (Copenhagen)	Present	-	Nighttime taxi drivers	33.3
Häkkänen & Summala (2000)	Finland	Past	3 months	Commercial truck drivers	29.6
Benbadis, Perry, Sundstad, & Wolgamuth (1999)	USA (Madison, Wisconsin)	Present	-	Licensed drivers	28.7
Ozturk, Tufan, & Guler (2002)	Turkey	Present	-	Taxi and bus drivers	21
Connor et al. (2001)	New Zealand (Auckland)	Present	-	Drivers of cars & light vehicles	9.2
Dalziel & Job (1997)	Australia (Sydney)	Past	2 years	Taxi drivers	4.8

Table 2 Distribution of circadian types in daytime and nighttime taxi drivers in the screening sample and the experimental sample

Circadian type	MEQ score	Screening sample		Experimental sample	
		Daytime	Nighttime	Daytime	Nighttime
Morning	0 - 52	18	1	14	0
Neither	53 - 64	30	10	1	8
Evening	65 - 86	8	44	1	8

Note: MEQ = Morning-Evening Questionnaire

Table 3 Mean and standard deviation of sleep quality and quantity, sleepiness, and performance in the Continuous Performance Test and simulated driving task

	Shift	Day/Night 1 TP1	Day/Night 1 TP2	Day/Night 1 TP3	Day/Night 2 TP1	Day/Night 2 TP2	Day/Night 2 TP3	Day/Night 3 TP1	Day/Night 3 TP2	Day/Night 3 TP3
Sleep										
Quality	Day	2.00 (0.63)	-	-	-	-	-	-	-	-
	Night	1.69 (0.60)	-	-	1.81 (0.98)	-	-	2.19 (0.66)	-	-
Quantity	Day	7.00 (1.06)	-	-	-	-	-	-	-	-
	Night	7.31 (1.77)	-	-	7.47 (2.62)	-	-	6.41 (1.67)	-	-
Sleepiness	Day	1.94 (0.85)	2.38 (1.19)	2.50 (1.32)	-	-	-	-	-	-
	Night	1.94 (1.28)	2.50 (1.22)	3.19 (1.65)	2.03 (1.19)	3.19 (1.59)	3.53 (1.84)	2.25 (0.95)	3.03 (1.27)	3.69 (1.71)
CPT										
RT	Day	629.56 (113.16)	632.56 (122.30)	633.95 (110.48)	-	-	-	-	-	-
	Night	566.13 (112.03)	587.43 (119.35)	608.56 (135.81)	608.34 (140.56)	604.18 (141.48)	618.61 (138.09)	618.21 (139.61)	619.65 (129.09)	641.01 (136.02)
OMER	Day	3.13 (3.96)	3.56 (6.00)	1.69 (3.09)	-	-	-	-	-	-
	Night	3.06 (2.98)	2.63 (2.50)	3.00 (4.55)	3.94 (5.28)	3.31 (4.99)	3.69 (5.83)	3.25 (4.57)	2.81 (3.31)	2.75 (4.33)
COER	Day	1.81 (4.71)	1.00 (2.73)	0.25 (0.45)	-	-	-	-	-	-
	Night	3.19 (4.96)	1.06 (2.72)	0.56 (0.73)	0.81 (1.80)	0.56 (0.81)	0.38 (0.62)	0.25 (0.58)	0.38 (0.72)	0.31 (0.48)
Driving										
Lights										
RT	Day	649.95 (81.12)	620.25 (77.66)	609.04 (74.10)	-	-	-	-	-	-
	Night	640.36 (76.00)	604.52 (84.60)	606.01 (78.36)	607.89 (85.90)	607.86 (69.99)	625.11 (64.68)	622.27 (77.53)	615.06 (78.34)	621.26 (62.00)
MISS	Day	0.44 (1.03)	0.13 (0.34)	0.19 (0.54)	-	-	-	-	-	-
	Night	0.50 (0.63)	0.44 (0.89)	0.44 (0.73)	0.31 (1.08)	0.31 (0.60)	0.50 (1.10)	0.13 (0.34)	0.25 (0.45)	0.19 (0.40)
FA	Day	0.00 (0.00)	0.13 (0.34)	0.63 (0.25)	-	-	-	-	-	-
	Night	0.13 (0.34)	0.19 (0.54)	0.31 (0.79)	0.25 (1.00)	0.63 (0.25)	0.19 (0.54)	0.13 (0.50)	0.19 (0.75)	0.00 (0.00)
Pedestrians										
RT	Day	669.04 (79.23)	694.16 (68.91)	678.05 (56.83)	-)	-	-	-	-	-
	Night	688.45 (72.52)	676.78 (75.34)	706.96 (63.40)	663.56 (86.93)	694.06 (66.73)	713.77 (68.17)	695.56 (71.09)	696.16 (56.81)	721.30 (59.28)
MISS	Day	0.25 (0.58)	0.13 (0.34)	0.13 (0.34)	-	-	-	-	-	-
	Night	0.63 (0.72)	0.25 (0.58)	0.19 (0.40)	0.38 (0.81)	0.44 (0.73)	0.19 (0.40)	0.00 (0.00)	0.19 (0.40)	0.13 (0.34)
FA	Day	1.31 (1.96)	1.19 (1.87)	0.63 (1.15)	-	-	-	-	-	-
	Night	1.31 (2.44)	0.88 (1.20)	0.81 (1.38)	0.88 (1.02)	0.63 (0.25)	0.63 (0.25)	0.38 (1.02)	0.63 (0.25)	0.25 (0.77)

Note: TP = test period; CPT = Continuous Performance Test; RT = reaction time; OMER = number of omission errors; COER = number of commission errors; MISS = Number of misses; FA = Number of false alarms

Table 4 *F* values of repeated measures ANOVAs on the effects of shift and time on sleepiness, and performance in the Continuous Performance Test and simulated driving task

	Shift	Time	Shift x Time
Sleepiness	.53	8.60*	1.40
Continuous Performance Test			
Mean reaction time	1.27	1.74	1.15
Number of omission errors	.01	.74	1.28
Number of commission errors	.48	5.27*	.55
Simulated driving			
Traffic lights			
Mean reaction time	.13	12.82*	.31
Number of misses	1.54	.70	.29
Number of false alarms	1.63	.91	.49
Pedestrians			
Mean reaction time	.25	.70	2.20
Number of misses	4.01	2.63	.76
Number of false alarms	.01	2.14	.39

Note: * $p < .05$

Table 5 Correlation between sleep quality and quantity, sleepiness, performance in Continuous Performance Test and simulated driving task

	Sleep		Sleepiness			CPT (TP 1)			Simulated Driving (TP 1)					
									Traffic lights			Pedestrians		
	Quality	Quantity	TP 1	TP 2	TP 3	RT	OMER	COER	RT	MISS	FA	RT	MISS	FA
Sleep														
Quality	1.00	-.06	.20	.03	.27	.02	.08	.19	.15	-.10	-.14	.17	.01	.08
Quantity	-.06	1.00	-.38*	-.13	.25	.18	.26	-.43*	.04	.22	.15	.06	.04	-.03
TP 1 sleepiness	.20	-.38*	1.00	.61*	.25	-.12	-.20	.01	.16	-.34	.02	.08	-.05	.13

Note: * $p < .05$
TP = Test period
CPT = Continuous Performance Test
OMER = number of omission errors
COER = number of commission errors
MISS = Number of misses
FA = Number of false alarms

Table 6 Results of hierarchical regression on the mediation effect of sleepiness on the relationship between sleep quantity and the number of commission errors in test period 1 in day / night 1

	R^2	ΔR^2	F	β
Model 1	.18	-	6.62*	-
Sleep quantity	-	-	-	-.43*
Model 2	.21	.03	3.78*	-
Sleep quantity	-	-	-	-.49*
Sleepiness	-	-	-	-.17

Note: * $p < .05$

Table 7 *F* values of repeated measures ANOVAs on the effects of treatment and time on sleep quality and quantity, sleepiness, and performance in the Continuous Performance Test and simulated driving task with light intensity as a covariate

	Treatment	Time	Treatment x Time
Sleep			
Quality	1.91	-	-
Quantity	.61	-	-
Sleepiness	2.08	12.36*	.67
Continuous Performance Test			
Mean reaction time	5.85*	4.53*	1.27
Number of omission errors	.49	1.38	.74
Number of commission errors	.32	.07	.16
Simulated driving			
Traffic lights			
Mean reaction time	.32	.92	.57
Number of misses	.12	4.76*	2.70*
Number of false alarms	.06	2.71	1.49
Pedestrians			
Mean reaction time	.50	.33	1.95
Number of misses	1.15	.88	1.53
Number of false alarms	4.05	2.67	2.35

Note: * $p < .05$

Appendix 1 The screening questionnaire

<u>第一部分:</u>

請細閱以下各條問題,並順次序回答.請獨自回答各問題,不要回溯之前的答案.請於每條問題只圈出一個答案.有些題目有一量表而非選擇性答案,請於量表上適當位置打一¨✓¨號.如有需有,請隨意於各問題後寫下任何詳情/意見.

1. 若你能完全自由地安排自己當天的節目,請考慮在自己感覺最好的情況下,你會在什麼時候起床?

   11:00-12:00 (中午) / 10:00-10:59 / 07:45-09:59 / 06:30-07:44 / 05:30-06:29

2. 若你能完全自由地安排自己當天晚上的節目,請考慮在自己感覺最好的情下,你會在什麼時候睡覺?

   01:45-03:00 / 00:30-01:44 / 22:30-00:29 / 21:00-22:29 / 20:00-20:59

3. 假若你要在某指定時間起床,你有多需要依賴鬧鐘才能起床?

   非常依賴 / 頗依賴 / 少許依賴 / 不太依賴

4. 在正常情況下,你覺得早上起床有多容易?

   完全不容易 / 不太容易 / 頗容易 / 非常容易

5. 在你早上起床後的首半小時內,你覺得你的警覺性有多高?

   十分低 / 頗低 / 頗高 / 非常高

6. 在你早上起床後的首半小時內,你的食慾有多強?

   完全不強 / 不太強 / 頗強 / 非常強

7. 在你早上起床後的首半小時內,你會感到有多疲累?

   十分疲累 / 頗疲累 / 頗精神 / 非常精神

8. 假若你在第二天沒有任何節目,你會在什麼時候睡覺? (與你平日睡覺時間相比)

   遲超過兩小時睡 / 遲一至兩小時睡 / 遲少過一小時睡 / 很少或從不遲睡

9. 假設你已經決定參與一些體能運動,而你的一位朋友建議你每星期做兩次該運動,每次約一小時,他認爲最適合他自己的時間爲早上七至八時.你不需要考慮其他因素,只需要考慮感覺最好的情況,你覺得你在那時間的運動表現會如何?

有很多困難 / 有困難 / 合理 / 出色

10. 在晚上什麼時間你會覺得疲倦因而有睡覺的需要?

02:00-02:59 / 00:45-01:59 / 22:15-00:44 / 21:00-22:14 / 20:00-20:59

11. 在一個將會需要用腦力及持續兩小時的測驗中,你希望有最好的表現.假若你可以完全自由地安排測驗那天的節目及只需要考慮感覺最好的情況,你會選擇下列四項中哪一時間進行測驗?

19:00-21:00 / 15:00-17:00 / 11:00-13:00 / 08:00-10:00

12. 如果你在晚上十一時睡覺,在那時侯你會覺得有多疲倦?

完全不疲倦 / 少許疲倦 / 頗疲倦 / 非常疲倦

13. 因某些原因你比正常時間遲了幾小時睡覺,但於翌日早上你並不需要在特定時間起床.以下那一項最可能發生於你身上?

不會起床直至遲過平日起床的時間 /
和平日一樣時間起床,但<u>會</u>再睡 /
和平日一樣時間起床,並會於之後¨鐘眼訓¨ /
和平日一樣時間起床,並<u>不會</u>再睡

14. 假設有一個晚上,你需要在凌晨四時至六時保持清醒去做夜更,但你在翌日並沒有任何節目.下列那一處理方法最適合你?

不會睡覺直至做完夜更 /
於做夜更前小睡一會及做完夜更後睡一覺 /
做夜更前睡一覺及做完夜更後小睡 /
於做夜更前睡<u>所有</u>覺 (即之後不會小睡或睡覺)

15. 假設你需要完成兩小時的體力耗支工作,而你可完全自由地安排那天的節目.只需要考慮感覺最好的情況下,你會選擇下列那一時段去做那些工作?

19:00-21:00 / 15:00-17:00 / 11:00-13:00 / 8:00-10:00

16. 假設你將會參與一項嚴重體力耗支的運動.一位朋友建議你每星期做那運動兩次,每次一小時.對他而言,最好時間爲晚上十至十一時.你不需要考慮其他因素,只需要考慮感覺最好的情況,你覺得你在那時間的運動表現會如何?

出色 / 合理 / 有困難 / 有很多困難

17. 假設你可選擇自己的工作時間,若你每天需要工作五小時 (包括休息時間),而你的工作是有趣及依工作表現給予工資的,你會選擇哪五個小時連續工作? 請¨✓¨以下其中五格:

□□□□□□□□□□□□□□□□□□□□□□□□□

12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12

□□ □□ □□

18. 以下那一時間是你一日內¨感覺最好¨的時候? 請¨✓¨以下其中一格:

□□□□□□□□□□□□□□□□□□□□□□□□□

12 1 2 3 4 5 6 7 8 9 10 11 12 1 2 3 4 5 6 7 8 9 10 11 12

□□ □□ □□

19. 有人說過有¨日間活動型¨及¨晚間活動型¨兩類人,你覺得自己是哪一種人?

肯定是¨晚間活動型¨ /
比較接近¨晚間活動型¨多於¨日間活動型¨ /
比較接近¨日間活動型¨多於¨晚間活動型¨ /
肯定是¨日間活動型¨

<u>第二部分: 日/夜的影響</u>

請於以下問題圈出你認爲最適合你的答案.

		完全沒有影響				影響非常大
1.	日/夜更的工作對你採用你喜歡的方法(例如:運動,嗜好等)去打發餘暇有多大的影響?	1	2	3	4	5
2.	日/夜更的工作對你工餘時間在家<u>中</u>需要做的工作(例如:家務,照顧孩子等)有多大的影響?	1	2	3	4	5
3.	日/夜更的工作對你工餘時間在家<u>外</u>需要做的工作(例如:看醫生,去圖書館/銀行,剪頭髮等)有多大的影響?	1	2	3	4	5

<u>第三部分: 個人資料</u>

性別:

年齡:

更(現時): 日 / 夜

年資:

更(以往): 日 / 夜

年資:

願意 / 不願意 參與日後之實驗

願意者, 電話: _____; 稱呼: _____; 車牌號碼:

十分多謝你的參與!

Appendix 2 Sleepiness countermeasure items

對抗瞌睡/提升警覺性的方法

請指出你於上一個非測試時段內有否採用下列對抗瞌睡/提升警覺性的方法,先用

¨✓¨選擇¨有/沒有¨,然後填寫¨有¨的答案的詳情.

	有	沒有	詳情	(若有)
喝咖啡	☐	☐	___杯	時間:__________
喝水	☐	☐	___杯	時間:__________
喝可樂	☐	☐	___杯	時間:__________
喝酒	☐	☐	___杯	時間:__________
抽煙	☐	☐	___枝	時間:__________
吃香口膠	☐	☐	___粒	時間:__________
服用興奮劑	☐	☐	___次	時間:__________
聽收音機	☐	☐	___分鐘	時間:__________
打開窗戶	☐	☐	___次	時間:__________
與乘客交談	☐	☐	___分鐘	時間:__________
洗臉	☐	☐	___次	時間:__________
想念家人	☐	☐	___次	時間:__________
看風景	☐	☐	___分鐘	時間:__________
調校椅子	☐	☐	___次	時間:__________
小睡	☐	☐	___分鐘	時間:__________
吃零食	☐	☐	___次	時間:__________
做運動	☐	☐	___分鐘	時間:__________
用手提電話談天	☐	☐	___分鐘	時間:__________
赤腳駕駛	☐	☐	___分鐘	時間:__________
聽音樂	☐	☐	___分鐘	時間:__________
放鬆自己	☐	☐	___分鐘	時間:__________
調校空調溫度	☐	☐	___次	時間:__________

經常停下不工作	☐	☐	____分鐘	時間:____________
想起及解決有關工作的問題	☐	☐	____分鐘	時間:____________
獨自唱歌或說話	☐	☐	____分鐘	時間:____________
工作前睡覺	☐	☐	____小時	時間:____________
用無線電與同行談天	☐	☐	____分鐘	時間:____________

其他:

________________	____次/分鐘 時間:____________
________________	____次/分鐘 時間:____________
________________	____次/分鐘 時間:____________
________________	____次/分鐘 時間:____________
________________	____次/分鐘 時間:____________